WATER PRODUCTIVITY TOWARDS FOOD SECURITY – WATER AND LAND PRODUCTIVITY CHALLENGES

PRODUCTIVITE DE L'EAU VERS LA SECURITE ALIMENTAIRE – DEFIS QUE POSE LA PRODUCTIVITE DE L'EAU ET DE LA TERRE

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ABSTRACT

Diminishing fresh water resources for irrigated agriculture in the developing countries burdened with greater food and fiber demand is causing a great concern. Population growth along with competition from other sectors for water resources is shrinking the amount of water available for agriculture. In this situation expanding the area of irrigable land is neither feasible nor economical. The most logical solution is increasing food production through raising water productivity (more food per water drop). However careful attention is needed to prevent degradation of water and land resources which is caused by using less water. While producing more food per unit of land and water, its sustainability also is no less an important issue.

The work reported in this paper was devoted to water productivity evaluation of three major crops namely, rice, wheat and corn, in Iran that covers about 55 percent of total land under field crops.

Water productivity (water use efficiency) for these crops was calculated for each province in Iran on the basis of evapotranspiration (ET) or evapotranspiration minus effective rain (ET-ER). The results obtained were compared to the result of other works available from the literature. It was found that WPET for rice in Iran was very low compared to other places. WPET of wheat was not bad, but it needed a lot of effort and investments to reach optimum values. Water productivity of corn was the best among the three crops studied.

On the basis of this work, the states having advantages in producing a specific crop as far

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water productivity is concerned must be assisted to implement procedures recommended by this paper to reach a higher water productivity level.

Key words: *water productivity, agriculture, food security, evapotranspiration.*

RESUME

La diminution des ressources en eau fraîche en agriculture irriguée dans les pays en voie de développement accompagnée de la demande croissante de la nourriture et du fibre pose une grande préoccupation. La croissance démographique avec la concurrence d'autres secteurs pour les ressources en eau réduit la quantité d'eau disponible pour l'agriculture. Dans cette situation, l'expansion de la terre irriguée n'est pas viable de manière économique. Il faut augmenter la production alimentaire tout en augmentant la productivité de l'eau (plus de nourriture par goutte). Cependant, il est nécessaire d'empêcher la dégradation des ressources en eau et terre. Tout en produisant plus de nourriture par unité de l'eau et de terre, il faut accorder une grande importance à sa durabiltié.

Le rapport est consacré à l'évaluation de la productivité de trois cultures principales en Iran à savoir, le riz, le blé et le maïs, qui couvrent 55% de la superficie totale cultivée.

La productivité de l'eau (efficience d'utilisation de l'eau) de cette culture a été calculée pour chaque province de l'Iran sur la base de l'évapotranspiration (ET) ou de l'évapotranspiration moins la pluie efficace (ET-ER). Les résultats obtenus ont été comparés avec le résultat d'autres travaux disponibles. Il a été constaté que WPET pour le riz en Iran était très bas par rapport à d'autres sites. WPET de blé n'était pas mal, mais il exigeait beaucoup d'effort et d'investissements pour atteindre les valeurs optimums. La productivité de l'eau de maïs était le mieux parmi les trois cultures étudiées.

Compte tenu de cette étude, les états ayant des avantages dans la production d'une culture spécifique en ce qui concerne la productivité de l'eau doivent être soutenus pour mettre en oeuvre les procédures recommandées par ce rapport pour réaliser un niveau plus élevé de la productivité de l'eau.

Mots clés : *Productivité de l'eau, agriculture, sécurité alimentaire, évapotranspiration.*

1. INTRODUCTION

Scarce water resources and growing competition for water will reduce its availability for irrigation. At the same time, the need to meet the growing demand for food will require increased crop production from less water. Achieving greater efficiency of water use will be a primary challenge for the near future, keeping in mind the issue of land productivity and sustainability of the environment.

Unplanned population growth of the developing countries around the globe along with the employment of more modern technologies imported from the developed countries in the second half of the twentieth century without enforcing proper environmental laws and regulations has caused immense damage to almost all the natural resources including water, land, plant and animal resources.

Iran, one of the developing countries, is experiencing the same unfortunate trend. Degradation of our land and water quality during recent years is assuming alarming proportions mainly due to over exploiting water and land resources and more frequent incidence of annual droughts. Since the present trend of degrading our natural resources is un-acceptable, therefore for survival we must make drastic changes in this regard and follow the examples of developed countries for saving our natural resources.

The world average annual population growth is 1.3 per cent. In 2025, the world population will probably reach 7.9 billion with 80 per cent belonging to the developing countries (U.N, 1998). Population of Iran in 2025 with U.N medium growth rate will reach 89 million (Al Yasin, 1384 Iranians Solar calendar: 2005 A.D.) with a growth rate of 1.2 per cent to continue beyond that date. The same source is quoting Falcon Mark theory on water shortage concerning water stress and water crisis conditions in the world: If renewable water resources reaches 1667 $m^3 Capita^{-1} year^{-1}$, we have water stress and if it reaches 1000 $m^3 Capita^{-1} year^{-1}$, then we enter the water crisis phase. At present annual renewable water per capita on the basis of 75 million populations is equal to 1733 m^3 and if Iran's population reaches 130 million, this figure becomes 1000 m^3.

According to the above figures the status of water resources in Iran is quite critical and it is necessary to start correcting the situation right now. Main concern is in fact combined aridity and drought conditions which are both natural phenomenon. Unfortunately, aridity phenomena is permanent and causes desertification, while drought phenomena is temporary and causes water shortages.

Aridity is often associated with high pressure on natural resources, strong competition for water that aggravates the limiting resource for agriculture, frequent soil salinization due to poor management of irrigation, and vulnerable and fragile ecosystems.

Water management under drought require measures and policies which are common with aridity such as those to avoid water wastage, reduce demand, make water use more efficient or increase the public awareness on the proper use of scarce water resources.

Objectives of this paper can be summarized as follows:

(1) Addressing food security through increasing water productivity in agriculture,

(2) Ways to reach optimum water productivity from one unit of consumed water,

(3) Agricultural water productivity on a global basis for Iran,

(4) Comparison of water productivity of most important crops in Iran with figures in other scientific sources, and

(5) Challenges in water and land productivity.

2. WATER PRODUCTIVITY IN AGRICULTURE

Higher water productivity in agriculture means producing more crops, livestock, fish, and forest product per unit of agricultural water use. This holds a key to both food and environmental security.

Water productivity that sometimes is referred to as water utilization efficiency is defined by various workers according to the intended use. In this paper we adopt the definition as: The weight of produced crop with moisture content equal to the moisture of marketable produce per unit of water consumed in evapotranspiration (i.e. moisture content of 13-15% for wheat). This quantity is shown as WP_{ET}.

Due to a large increase of population in developing countries, nearly all of the potential water resources has been employed in crop production;, more often due to a lack of scientific planning in agricultural water consumption. Unless innovative solutions are found, over exploitation of water resources will continue the threat. The sustainability of the agricultural development projects depends on water resources.

3. MAINTAINING FOOD SECURITY THROUGH INCREASING WATER PRODUCTIVITY

Food security means producing enough food and fiber to meet the demand of every member of the community within a country. According to the concept of virtual water, it also means exporting less water consuming products and importing more water consuming agricultural produce in lieu. This concept of virtual water is relevant for water-scarce countries such as Iran.

To reach food security in the second half of the 20 th century most countries including Iran followed an agricultural policy of increasing the area under irrigated agriculture. In a normal year in regard to water resources such as 1385-1386 crop year (2006-2007 A.D.) the irrigated land equaled about nine million hectares (Agricultural Statistics , 2009) while 30 years ago it was only 4.5 million hectares. With respect to huge investments in utilization of water resources with very low irrigation efficiencies, it seems that increasing the area of irrigated cultivated land is not feasible or economical. Therefore, the only way for raising agricultural production may be through increased water productivity.

This very general goal of food security must be fulfilled by implementing strategies and techniques which should come about and tested at field levels for increasing food production, saving irrigation water used, and finally increasing water use efficiency. Among the techniques of increasing WUE, are supplemental irrigation and water harvesting. Other existing strategies are related to crops variety selection, cropping pattern, planting practices and agricultural inputs. The techniques and inputs have been tested in agricultural research stations or selected farms. Employing WUE techniques used in farms of the entire watershed or the total irrigation commad requires considerable efforts.

4. WAYS TO REACH OPTIMOM PRODUCTIVITY FROM A UNIT OF WATER USED

Although plant species, genotypes and available solar radiation are vitally important in water productivity, often water is the most critical element in agricultural production (Howell, 2001). On field scale Batchelor (1997) has suggested four means for improving WUE which are as follows:

- **Agronomical:** plant management in catching rainwater or reducing evaporation, improvement of plant species, advanced strategies that maximize cropping area during periods of low water demand and/or during periods of maximum precipitation probability,

- **Engineering:** Irrigation systems that reduce water losses during irrigation, improve distribution uniformity, and planting systems that can improve interception of precipitation.

- **Managing – Irrigation schedule on demand basis:** slight to moderate deficit irrigation so that plant roots can absorb water from deeper soil profile, prevention of yield reduction by salinity of root zone, and using preventive methodsto forestall system failure.

- **Institutional:** Water users share in operation and maintenance of irrigation schemes, logical water pricing and enforcing legal incentive in water saving and levying penalties for inefficient water use, teaching and training of water users and irrigation staff in learning advanced techniques.

In recent years the developed countries with large parcels of irrigated land for improving water productivity have focused on irrigation water use learning centers in which studying plant systems is composed of genetics, agronomic practices, and bio- technology processes including water use efficiency technologies such as drought resistant crop systems. In fact bio–technology streams not only study seeds, but will concentrate on how bio–technology, agronomic practices and genetics will work together.

In this paper our attention will be focused on engineering and agronomic part of water productivity and subjects of genetic and plant breeding strategies are omitted.

5. PRESENT AGRICULTURAL WATER PRODUCTIVITY IN IRAN

As pointed out earlier, at present about 9 million hectares (Mha) of annual and perennial crops are consuming about 90 billion cubic meters (BCM) of water annually and on the basis of 110 BCM of safe water with drawal a maximum of 100 BCM of water can be safely devoted to agricultural use. With the amount of extra water only 1 Mha of irrigated crops may be added to the present cultivated area and therefore it seems the only alternative to expand cultivated area or increasing agricultural production is through increasing water productivity.

Annual water productivity for rice, wheat and corn in 2006-2007 agricultural year for an area of 3,704,320 hectares (55% of total cropped area) was computed (Table 1) for each state. Crop yields were obtained from 2006-2007 data collected by ministry of Jahad Kashavarzi and actual evapotranspiration based on FAO CROPWAT computer program was obtained from Farshi et al. (1997).

Table 1. Irrigated crops acreage, yield, WP_{ET} and WP_{ET-ER} of three important crops for each province (2006-2007 agricultural year).

Province	Wheat				Rice with bran (shelled rice)*			
	Cultivated area (ha)	Yield (kg/ha)	WP_{ET} (kgm^{-3})	$WP_{(ET-ER)}$ (kgm^{-3})	Cultivated area (ha)	Yield (kg/ha)	WP_{ET} (kgm^{-3})	$WP_{(ET-ER)}$ (kgm^{-3})
West Azarbaijan	118,316	3045	0.57	0.98	-	-	-	-
East Azarbaijan	96,491	3610	0.68	1.06	1830	3549	0.24(0.16)	0.25(0.16)
Ardebil	76,015	4026	0.78	1.26	-	-	-	-
Mazandaran	3,038	2662	0.76	1.74	209,037	4799	0.50(0.32)	0.59(0.38)
Golestan	160,364	3627	0.71	1.45	61,741	4371	0.35(0.23)	0.39(0.25)
Markazi	91,850	3881	0.58	0.77	-	-	-	-
Tehran	77,435	4515	0.74	1.03	-	-	-	-
Hamedan	97,196	3895	0.63	0.96	-	-	-	-
Lorestan	65,155	2975	0.45	.63	5,327	3113	0.20(0.13)	0.20(0.13)
Esfahan	110,180	4845	0.70	1.14	17,452	5696	0.35(0.23)	0.36(0.23)
Charmahal& Bakhtiari	28,946	3603	0.59	0.91	3,275	5562	0.39(0.25)	0.39(0.25)
Khozistan	403,667	3421	0.59	0.86	51,425	3751	0.23(0.15)	0.23(0.15)
Ilam	47,889	3662	0.70	1.22	3,314	4878	0.35(0.23)	0.36(0.23)
Kermanshah	90,228	5212	0.97	1.60	-	-	-	-
Kurdistan	35,033	4112	0.74	1.10	-	-	-	-
Fars	481,988	4725	0.71	0.96	46,044	4826	0.35(0.23)	0.35(0.23)
Bushehr	22,461	2561	0.43	0.62	-	-	-	-
Yazd	27,037	3502	0.49	0.54	-	-	-	-
Kerman	58,353	3831	0.58	0.73	-	-	-	-
Hormozgan	13,540	4443	0.82	1.15	-	-	-	-
Sistan & Balochestan	87,282	2192	0.35	0.40	2,377	2720	0.16(0.10)	0.18(0.10)
Zanjan	21,205	3851	0.61	0.83	-	-	-	-
Khorasan	377,161	3180	0.54	0.74	2,032	3690	0.26(0.17)	0.27(0.17)
Kohkilueh & Bovir Ahmad	30,611	3136	0.59	0.95	8,064	4707	0.37(0.24)	0.37(0.24)
Semnan	29,513	4310	0.71	0.86	-	-	-	-
Gilan	-	-	-	-	197,180	3764	0.41(0.27)	0.53(0.34)
Sum (ha)	2,781,939				615,910			
Weighted mean			0.63				0.40(0.26)	

*: In order to calculate values for shelled rice, rice and bran figure is multiplied by a factor of 0.65. Values inside the parenthesis are for shelled rice.

Table 1 continued. Irrigated crops acreage, yield, WP_{ET} and $WP_{(ET-ER)}$ of three important crops for each province (2006-2007 agricultural year)

Province	Maize			
	Cultivated area (ha)	Yield (Kg/ha)	WP_{ET} (kg m^{-3})	$WP_{(ET-ER)}$ (kg m^{-3})
West Azarbaijan	3,793	6219	0.84	0.95
East Azarbaijan	536	6806	1.30	1.36
Ardebil	11,139	6944	1.12	1.26
Mazandaran	—	—	—	—
Goletan	—	—	—	—
Hamedan	10,434	8806	1.38	1.52
Lorestan	6,782	8693	1.22	1.34
Esfahan	2,006	6898	0.87	0.88
Charmahal & Bakhtiari	29	3396	0.52	0.53
Khuzistan	75,818	6615	0.95	0.99
Ilam	4,107	6525	1.00	1.07
Kermanshah	40,121	8731	1.20	1.25
Kurdistan	1,404	8262	1.24	1.26
Fars	92,996	8098	0.99	1.02
Bushehr	1,201	8681	1.24	1.24
Yazd	4,017	8640	1.06	1.06
Kerman	14,501	7252	1.06	1.08
Hormozgan	5,586	6965	0.98	1.00
Sistan & Bauchestan	3,779	3777	0.52	0.52
zanjan	—	—	—	—
Khorasan	942	5786	0.69	0.71
Kohkilueh & Bouir Ahmand	2,381	7339	1.22	1.23
Semnan	118	4016	0.57	0.58
Gilan	—	—	—	—
Sum(ha)	**306.473**			
Weighted mean			**1.03**	

The last column for each crop shows water productivity on the basis of ET minus effective rain (WP_{ET-ER}) deducted from actual evapotranspiration. This quantity shows the relative advantages of some states with higher rainfall in crop production.

In this table water productivity on the basis of actual evapotranspiration is given. For example WP_{ET} wheat in various states ranges from a minimum 0.35 kg/m^3 of evapotranspired water in Sistan and Baluchestan province to a maximum of 0.97 kg/m^3 water in Kermanshah province. Since wheat cultivated area in various provinces varies, therefore weighted WP_{ET} was calculated, which was 0.63 kg/m^3 of evapotranspired water. Minimum and Maximum water productivity for rice and corn were respectively, 0.15 and 0.58; and 0.52 and 1.3 kg/m^3 of water consumed. Weighted mean for these two crops were 0.26 and 1.03 kg/m^3. An advantage of each province in growing these three crops is shown in Table 1. The best wheat growing states after Kermanshah are Hormozgan, Ardebil, Mazandaran, Kurdistan, Tehran, Fars, Golestan, Semnan, Isfahan and Ilam with WP_{ET} above 0.7kg/m^3 water consumed. In rice production, Mazandaran and Gilan provinces and for corn production, Hamedan, East Azarbaijan, Kurdistan, Bushehr, Lorestan, Kohkiluieh and Boviarahmad and Kermanshah had higher water productivities. Compared to FAO values (Table 2) the rice productivity in Iran is low. It is recommended that rice must be grown only in a few states and its cultivation in other states stopped.

Table 2. Water productivity of wheat, rice and maize according to various sources in kg/m^3 of water used.

Crops	WP_{ET} (Present article)	WP_{ET} (FAO Publication No. 33-1979)	WP_{ET} (farmers field sin Sirsa, 2003)	WP_{ET} (Simulated in Sirsa, 2001-2007)	WP_{ET} (Asadi & Aghili, 2010)	WP_{ET} (Shayanfar, 2003)
Wheat	0.63 (weighted) (0.35-0.97)*	0.8-1.0	1.28 (0.06-1.60)*	2.1	0.6-1.7	1.1
Rice	0.40 (weighted) (0.16-0.50)	0.7-1.1	1.13 (0.81-2.10)	0.80	0.6-1.6	0.18
Maize	1.03 (weighted) (0.57-1.38)	0.8-1.6			1.1-2.7	0.50

*: Figures inside parenthesis are minimum and maximum WPET of this article.

6. COMPARING WATER PRODUCTIVITIES OF SOME IMPORTANT CROPS TO THOSE IN SCIENTIFIC LITERATURES

Computing agricultural water productivity on the basis of gross water use of crops is not accurate since irrigation efficiencies of various irrigation methods in different parts of the world are quite different. The value of irrigation efficiency even in one irrigation method can vary due to variation in soil texture and structure, land preparation, size of the field and crop types. Deep percolation which may be used by downstream water users can not be considered a total loss.

The International Food Policy Research Institute (IFPRI) recently performed research on water productivity with assumptions slightly different from FAO (Cai and Rosegrant, 2003).

Table 3 was given by these researchers for estimated and predicted water productivity, water consumption, unit crop yield for rice and other cereals in 1995 and 2021-2025.

Table 3. Estimated and predicted water productivity, water consumption and unit yield of rice and other cereals (source: Cai and Rosegrant, 2003)

Crop	1995 (estimated)	Predicted for 2021-2025(mean)		
		Base	Higher basin efficiency	Higher basin efficiency and lower with drawl
Rice (WP in kg/ m^3 of water):				
Developing Countries	0.39	0.53	0.56	0.58
Developed Countries	0.47	0.57	0.61	0.63
Water consumption per hectare (m^3):				
Developing Countries	8580	8445	8040	7510
Developed Countries	10200	9730	9100	8710
Other cereal (WP in kg/ m^3):				
Developing Countries	0.56	0.94	1.01	1.03
Developed Countries	1.00	1.32	1.45	1.50
Water consumption per hectare (m^3):				
Developing Countries	5720	5260	5040	4760
Developed Countries	4430	4530	4275	3980
Rice (yield in kg/hectare):				
Developing Countries	3310	4330	4530	4360
Developed Countries	4790	5520	5505	5455
Other cereals (yield in kg/hectares):				
Developing Countries	3185	4670	5165	4835
Developed Countries	4410	6000	6180	5980

Asadi and Aghili (2011) reviewing 84 recorded scientific sources from 1979 to 2004 in the world concluded that WP_{ET} reported by FAO in 1979 shows increasing trend so that for wheat, rice and maize this increase was in the order of 0.6 to 1.7, 0.6-1.6 and 1.1 to 2.7 (Table 2). It seems in that period (1979 to 2004) noticeable yield increase on unit area with plant breeding did not occur (Hsiao et al, 2007). Hence, yield increase shown in Asadi and Aghilli's figures may have been contributed by trial plot data from research stations.

Comparing WP_{ET} of this article and other works, it seems in large scale agricultural water resources such as a province, figures of FAO (Table 2) and Cai and Rosegrant (Table 3) can be applied with more confidence. Therefore it is recommended to use these figures for planning agricultural water resources as sign of increased water productivity both at present time and at Iran`s target development document which is set for 1404 solar year (2025 A.D.). It is recommended that at present time for wheat, rice and maize use water productivity figures of 1, 0.5 and 2 kg/m^3 evapotranspiration water may be adopted. For the target year (1404 solar year or 2025 A.D.) the figures used for water productivity of the above crops will be respectively equal to 1-2, 0.6 and 1.40 kg/m^3 of evapotranspiration water.

It is necessary to point out that according to Table 1; even in most fertile wheat producing states increasing water productivity to a value of 1, requires considerable efforts and investments. However, it is quite clear that as a whole we have not reached to a satisfactory level in water use efficiencies for our major crops in comparison to many of the developing countries. Therefore a comprehensive nationwide planning is to be backed by proper expert staff and adequate funding is required to reach the targets predicted by Cai and Rosegrant (Table 3).

7. CHALLENGES IN WATER AND LAND PRODUCTIVITY

Demand for food in developing countries in the coming years can never be met with an increase of new water resources. With growing competition from other sectors and very high cost in the development of new water resources, agriculture has to become more productive and we must produce more food from each unit of water used.

In irrigated crop production, there exists substantial opportunities to increase water productivity. Through advances in agricultural research and developing better performing varieties, it is possible to increase average farm crop yield by at least 30%. For our wheat acreage this means increasing 3.8 tons/ha to 5 tons/ha.

Moreover, introduction of more efficient irrigation technologies along with improving the existing surface irrigation methods will considerably reduce water losses and increase water use efficiencies.

In rain fed crop production, by using water harvesting techniques and preserving of soil moisture through conservation farming and adapting of drought resistant and drought tolerant crops can bring about greater water use efficiency.

The development and employment of innovative water technologies will require both investment and supporting research activities in the field of irrigation, drainage, and water conservation technologies as well as adequate training to farmers for adopting the developed technologies.

Reform in national water policies along with capacity building and training for water users to achieve more effective water management is another challenge in this regard.

According to Hsiao (2007), the ratio of yield of annual grain (or fruit) crops to water taken from reservoir outlet (m_{yld}/w_{vo}) in term of kilogram per cubic meter of water can range from 0.0243 for poor circumstances and practices to as high as 1.22. This is equal to a 50 fold room for improving water use efficiencies.

Aside from above advances, it is possible to improve mineral nutrition of root zone, changing location and date of growing crops under the lower evaporative demand, reducing soil erosion, reuse of drainage or runoff water, deficit and supplemental irrigation, dry land cropping, range vegetation for animal production, scaling up beyond the field level, virtual water trade, an etc. to improve water productivity.

According to Hsiao (2007) over the last century plant breeders have inadvertently selected for higher water use efficiency by selecting for higher yielding ability. The higher yields turned out to be mostly the result of partitioning more biomass to the grain or fruit and less vegetative parts. For example the efficiency of yield (E_{yld}) defined as the ratio of mass of yield to the mass of biomass for wheat and rice were in the range of 0.33 at the beginning of the 20th century and rose to as high as 0.53 in the 1980s. At the same time, efficiency for biomass production from transpired water appears to remain almost unchanged. Since 1980s there has been only marginal improvements in E_{yld} of there crops.

The most important challenges the developing world is facing now can be grouped into two very broad groups as follows :

a) Preventing lowering the quality of water resources by scaling down agricultural water use through increasing water productivity. In Iran and other developing countries there exists a very good opportunity to work on this, because our water productivity in agriculture is quite low.

b) Preventing the degradation of our land resources by implementing modern technologies developed so far in the developed countries to slow down or stopping completely the process of desertification of our land resources. Desertification is intensified by unwise use of water and land resources, the results of which has endangered many civilizations from the beginning of recorded history in the form of salinization, wind and water erosions.

8. CONCLUSIONS

This paper looked at water productivity an the basis of one unit of water evapotranspired (WP_{ET}) for 3 major farm crops namely wheat, rice and maize in Iran. Calculation showed a weighted WP_{ET} equal to 0.63, 0.26 and 1.03 for these crops respectively. According to FAO 33 in the irrigation and drainage series, the average WP_{ET} for wheat, rice and maize were respectively equal to 0.9, 0.9 and 1.2. For wheat and rice average WP_{ET} on farmers field in Sisra region of India were 1.28 and 1.13 (Bessembinder et al, 2003). Median WP_{ET} of wheat, rice and maize in Asadi and Aghili (2009) were respectively 1.15, 1.1 and 1.9 kg/m^3 of evapotranspiration. Shayanfar (2003) for wheat gave a valve of $WP_{(ET-ER)}$ equal to 1.1, for rice 0.18 and for maize 0.50, which are considerably less than the figures given in this article.

It is concluded that there is plenty of room to improve water productivity of farm crops and orchards in Iran. This goal must be achieved by implementing strategies and techniques that have been developed and approved as effective on-farm means for increasing crop production, saving water and potentially increasing water-use-efficiency. Among these proven effective WUE-boosting techniques are supplemental irrigation and water harvesting. Other available strategies are related to crop varietal selection, cropping pattern, cultural practices and farm inputs. These techniques and inputs have been tested on research station and farm levels in Iran and elsewhere. The challenge is to extend the available on-farm techniques for improving WUE to basin or agricultural plain level.

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